scientific bases of commercial geography should be laid; and his paper, combined with what is being done elsewhere, leads us to hope that that hitherto ill-used and profitless subject may yet be worthy of a high place in technical education. In the same magazine is the report of an address by M. Kropotkin on the study of geography, which we commend to all interested in this important subject.

AT the recent German Geographentag, Dr. Eschenhagen, of the Imperial Marine Observatory, described the results of his magnetic survey of the Harz Mountains, begun last autumn, and comprising about 3000 measurements. He has shown that no connection can be proved to exist between the ancient geological line of fracture of the Harz and the distribution of terrestrial magnetism, such as Naumann demonstrated in the case of Japan. Dr. Eschenhagen has extended his explorations in terrestrial magnetism over the whole of the north-west of Germany, so that, inasmuch as a similar survey of Austria-Hungary will be completed about 1892, our knowledge of the distribution of terrestrial magnetism in Central Europe has made a great advance.

DR. O. KRUMMEL contributes to the current number of *Petermann's Mitteilungen* an important paper on erosion through the agency of tidal currents, in which, by a careful examination of several specific instances, he endeavours to come to some conclusion as to the laws which govern the erosive work performed by the tides. There is paper of some practical importance on the suitability of Central Asia for Russian colonization, by General Annenkof.

THE number of the *Boletino* of the Lisbon Geographical Society is entirely occupied by a long paper in French, by M. A. Marques, giving a detailed account of the Samoan Islands in all their aspects. As a summary of our knowledge of these islands, the paper will be found useful.

IN the current number (4) of the *Mittheilungen* of the Vienna Geographical Society will be found the first part of a paper, by Herr Jankó, on the development and topography of the Rosetta mouth of the Nile.

DR. SCHWEINFURTH writes with great satisfaction of his journey in Hodeida, in Southern Arabia, in the early part of the present year. Among the places he visited were Khalife, at the foot of the Jebel Bura, Wolleje, the Jebel Melhān, Bajil, Hojela, Wossil, and Jebel Harrassa. The climate he found quite European, the nights bitterly cold, though it was hot enough for an hour or two in the middle of the day. Dr. Schweinfurth's botanical collections exceeded all his expectations; the mountain-slopes are covered with vegetation. He sent home some 600 species (1800 specimens), besides seeds and living plants.

IN a very able memoir published by the Danish Society of Northern Antiquaries (in English), Prof. Gustav Storm rediscusses the vexed question of the Vinland voyages of the Norse colonists of Greenland, for the purpose of determining as accurately as the data will permit the various lands mentioned in the old Sagas. "Helluland," Prof. Storm is inclined to think, must be Labrador; Markland corresponds to Newfoundland, and Vinland to Cape Breton Island and Nova Scotia.

MR. J. Y. BUCHANAN has been appointed Lecturer in Geography at the University of Cambridge.

IT is reported from Sydney that the New South Wales branch of the Royal Geographical Society is sending an explorer, Mr. Arthur J. Vogan, to gather information relative to the far interior. Mr. Vogan will travel northwards from Fort Bourke to Pitchiri Creek, on the Upper Mulligan (lat. 21° S.), and after exploring the country from that point to the Herbert River, will either make his way to the Gulf of Carpentaria or to Hughenden. Mr. Vogan intended leaving Sydney during May.

ALUMINIUM.[1]

CHEMISTS of many lands have contributed to our knowledge of the metal aluminium. Davy, in 1807, tried in vain to reduce alumina by means of the electric current. Oerstedt, the Dane, in 1824 pointed out that the metal could be obtained by treating the chloride with an alkali metal; this was accomplished in Germany by Wöhler in 1827, and more completely in 1845, whilst in 1854, Bunsen showed how the metal can be obtained by electrolysis. But it is to France, by the hands of Henri St. Claire Deville, in the same year, that the honour belongs of having first prepared aluminium in a state of purity, and of obtaining it on a scale which enabled its valuable properties to be recognized and made available, and the bar of "silver-white metal from clay," was one of the chemical wonders in the first Paris Exhibition of 1855. Now England and America step in, and I have this evening to relate the important changes which further investigation has effected in the metallurgy of aluminium. The process suggested by Oerstedt, carried out by Wöhler, and modified by Deville, remains in principle unchanged. The metal is prepared, as before, by a reduction of the double chloride of aluminium and sodium, by means of metallic sodium in presence of cryolite; and it is therefore not so much a description of a new reaction as of improvements of old ones of which I have to speak.

I may perhaps be allowed to remind my hearers that more than thirty-three years ago, Mr. Barlow, then secretary to the Institution, delivered a discourse, in the presence of M. Deville, on the properties and mode of preparation of aluminium, then a novelty. He stated that the metal was then sold at the rate of £3 per ounce, and the exhibition of a small ingot, cast in the laboratory by M. Deville, was considered remarkable. As indicating the progress since made, I may remark that the metal is now sold at 20*s.* per pound, and manufactured by the ton, by the Aluminium Company, at their works at Oldbury, near Birmingham. The improvements which have been made in this manufacture by the zeal and energy of Mr. Castner, an American metallurgist, are of so important a character, that the process may properly be termed the Deville-Castner process.

The production of aluminium previous to 1887, probably did not exceed 10,000 pounds per annum, whilst the price at that time was very high. To attain even this production required that at least 100,000 pounds of double chloride, and 40,000 of sodium should be manufactured annually. From these figures an idea of the magnitude of the undertaking assumed by the Aluminium Company may be estimated, when we learn that they erected works having an annually producing capacity of 100,000 pounds of aluminium. To accomplish this, required not only that at least 400,000 pounds of sodium, 800,000 of chlorine, and 1,000,000 of double chloride, should be annually manufactured, but in addition that each of these materials should be produced at a very low cost, in order to enable the metal to be sold at 20*s.* per pound.

The works, which now cover a space of nearly five acres, are divided into five separate departments, viz. (1) sodium; (2) chlorine; (3) chloride; (4) aluminium; and (5) foundry, rolling, wire mills, &c.

In each department an accurate account is kept of the production each day, the amount of material used, the different furnaces and apparatus in operation, &c. In this manner it has been found possible to ascertain each day exactly how the different processes are progressing, and what effect any modification has, either on cost, quantity, or quality of product. By this means a complicated chemical process is reduced to a series of very simple operations, so that whilst the processes are apparently complicated and difficult to carry out successfully, this is not the case now that the details connected with the manufacture have been perfected, and each operation carried on quite independently until the final materials are brought together for the production of the aluminium.

Manufacture of Sodium.

The first improvement occurs in the manufacture of sodium by what is known as the "Castner process." The successful working of this process marks an era in the production of sodium, as it not only has greatly cheapened the metal, but has enabled the manufacture to be carried out upon a very large scale with little or no danger. Practically, the process consists in heating fused caustic soda in contact with carbon whilst the former substance is in a perfectly liquid condition. By the process in vogue before the introduction of this method, it was always deemed necessary that special means should be taken to guard against actual fusion of the mixed charges, which, if it were to take place, would to a large extent allow the alkali and reducing material to separate. Thus, having an infusible charge to heat, requiring the employment of a very high temperature for its decomposition, the iron vessels must be of small circumference to allow the penetration of the heat to the centre of the charge without actually melting the vessel in which the materials are heated. By the new process, owing to the alkali being in a fused or perfectly liquid condition in contact directly with carbon, the necessity of this is avoided, and consequently, the reduction can be carried on in large vessels at a comparatively low temperature. The reaction taking place may be expressed as follows:—

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[1] The Friday evening discourse delivered by Sir Henry Roscoe, M.P., D.C.L., LL.D., V.P.R.S., at the Royal Institution of Great Britain, on May 3, 1889.

$$3NaHO + C = Na_2CO_3 + 3H + Na.$$

The vessels in which the charges of alkali and reducing material are heated are of egg-shaped pattern, about 18 inches in width at their widest part, and about 3 feet high, and are made in two portions, the lower one being actually in the form of a crucible, while the upper one is provided with an upright stem and a protruding hollow arm. This part of the apparatus is known as the cover. In commencing the operation, these covers are raised in the heated furnace through apertures provided in the floor of the heated chamber, and are then fastened in their place by an attachment adjusted to the stem; the hollow arm extends outside the furnace. Directly below each aperture in the bottom of the furnace are situated the hydraulic lifts, attached to the top of which are the platforms upon which are placed the crucibles to be raised into the furnace. Attached to the hydraulic lifts are the usual reversing valves for lowering or raising, and the platform is of such a size as, when raised, completely to fill the bottom aperture of the furnace. The charged crucible, being placed upon the platform, is raised into its position, the edges meeting those of the cover, forming an air-tight joint which prevents the escape of gas and vapour from the vessel during reduction, except by the hollow arm provided for this purpose. The natural expansion of the iron vessels is accommodated by the water-pressure in the hydraulic lifts, so that the joint of the cover and crucible are not disturbed until it is intended to lower the lift for the purpose of removing the crucible.

The length of time required for the first operation of reduction and distillation is about two hours. At the end of this time the crucibles are lowered, taken from the platforms by a large pair of tongs on wheels, carried to a dumping pit, and thrown on their side. The residue is cleaned out, and the hot pot, being again gripped by the tongs, is taken back to the furnace. On its way, the charge of alkali and reducing material is thrown in. It is again placed on the lift and raised in position against the edges of the cover. The time consumed in making the change is a minute and a half, and it only requires about seven minutes to draw, empty, recharge, and replace the five crucibles in each furnace. In this manner the crucibles retain the greater amount of their heat, so that the operation of reduction and distillation now only requires one hour and ten minutes. Each of the four furnaces, of five crucibles each, when in operation, are drawn alternately, so that the process is carried on night and day.

Attached to the protruding hollow arm from the cover are the condensers, which are of a peculiar pattern specially adapted to this process, being quite different from those formerly used. They are about 5 inches in diameter and nearly 3 feet long, and have a small opening in the bottom about 20 inches from the nozzle. The bottom of these condensers is so inclined that the metal condensed from the vapour issuing from the crucible during reduction, flows down and out into a small pot placed directly below this opening. The uncondensed gases escape from the condenser at the further end, and burn with the characteristic sodium flame. The condensers are also provided with a small hinged door at the further end, by means of which the workmen from time to time may look in to observe how the distillation is progressing. Previous to drawing the crucibles from the furnace for the purpose of emptying and recharging, the small pots each containing the distilled metal are removed, and empty ones substituted. Those removed each contain, on an average, about 6 pounds of metal, and are taken directly to the sodium casting shop, when it is melted and cast, either into large bars ready to be used for making aluminium, or in smaller sticks to be used.

Special care is taken to keep the temperature of the furnaces at about 1000° C., and the gas- and air-valves are carefully regulated, so as to maintain as even a temperature as possible. The covers remain in the furnace from Sunday night to Saturday afternoon, and the crucibles are kept in use until they are worn out, when new ones are substituted without interrupting the general running of the furnace. A furnace in operation requires 250 pounds of caustic soda every one hour and ten minutes, and yields, in the same time, 30 pounds of sodium and about 240 pounds of crude carbonate of soda. With the four furnaces at work, 120 pounds of sodium can be made every seventy minutes, or over a ton in the twenty-four hours. The residual carbonate, on treatment with lime in the usual manner, yields two-thirds of the original amount of caustic operated upon. The sodium, after being cast, is saturated with kerosene oil, and stored in large tanks holding several tons, placed in rooms specially designed both for security against either fire or water.

Chlorine Manufacture.

This part of the works is connected with the adjacent works of Messrs. Chance Bros. by a large gutta-percha pipe, by means of which, from time to time, hydrochloric acid is supplied direct into the large storage cisterns, from which it is used as desired for making the chlorine. For the preparation of the chlorine gas needed in making the chloride, the usual method is employed; that is, hydrochloric acid and manganese dioxide are heated together, when chlorine gas is evolved with effervescence, and is led away by earthenware and lead pipes to large lead-lined gasometers, where it is stored.

The materials for the generation of the chlorine are brought together in large tanks or stills, built up out of great sandstone slabs, having rubber joints, and the heating is effected by the injection of steam. The evolution of gas, at first rapid, becomes gradually slower, and at last stops; the hydrochloric acid and manganese dioxide being converted into chlorine and manganous chloride. This last compound remains dissolved in the "spent still liquor" and is reconverted into manganese dioxide, to be used over again, by Weldon's manganese recovery process. Owing to the difficulty of keeping up a regular supply of chlorine under a constant pressure directly from the stills, in order that the quantity passed into the sixty different retorts in which the double chloride is made can be regulated and fed as desired, four large gasometers were erected. Each of these is capable of holding 1000 cubic feet of gas, and is completely lined with lead, as are all the connecting mains, &c., this being the only available metal which withstands the corrosive action of chlorine. The gasometers are filled in turn from the stills, the chlorine consumed being taken direct from a gasometer under a regular pressure until it is exhausted; the valves being changed, the supply is taken from another holder, the emptied one being refilled from the still.

Manufacture of the Double Chloride.

Twelve large regenerative gas furnaces are used for heating, and in each of these are fixed five horizontal fire-clay retorts about 10 feet in length, into which the mixture for making the double chloride is placed. These furnaces have been built in two rows, six on a side, the clear passage-way down the centre of the building, which is about 250 feet long, being 50 feet in width. Above this central passage is the staging, carrying the large lead-mains for the supply of the chlorine coming from the gasometers. Opposite each retort, and attached to the main, are situated the regulating valves, connected with lead and earthenware pipes, for the regulation and passage of the chlorine to each retort. The valves are of peculiar design, and have been so constructed that the chlorine is made to pass through a certain depth of liquid, which not only, by opposing a certain pressure, allows a known quantity of gas to pass in a given time, but also prevents any return from the retort into the main, should an increase of pressure be suddenly developed in the retorts.

The mixture with which the retorts are charged is made by grinding together hydrate of alumina, salt, and charcoal. This mixture is then moistened with water, which partially dissolves the salt, and thrown into a pug mill of the usual type for making drain pipes, excepting that the mass is forced out into solid cylindrical lengths upon a platform alongside of which a workman is stationed with a large knife, by means of which the material is cut into lengths of about 3 inches each. These are then piled on top of the large furnaces to dry. In a few hours they have sufficiently hardened to allow of their being handled. They are then transferred to large waggons, and are ready to be used in charging the retorts.

The success of this process is in a great measure dependent—(1) on the proportionate mixture of materials; (2) on the temperature of the furnace; (3) on the quantity of chlorine introduced in a given time; and (4) on the actual construction of the retorts. I am, however, not at liberty to discuss the details of this part of the process, which have only a commercial interest. In carrying on the operation, the furnaces or retorts, when at the proper temperature, are charged by throwing in the balls until they are quite full, the fronts are then sealed up, and the charge allowed to remain undisturbed for about four hours, during which time the water of the alumina hydrate is completely expelled. At the end of this time the valves on the chlorine main are opened, and the gas is allowed to pass into the charged retorts. In the rear of each retort, and connected therewith by means of an earthenware pipe, are the condenser boxes, which are built in brick. These boxes are provided with openings or doors, and also with earthenware pipes, connected with a small flue for carrying off the uncondensed vapours to the large chimney. At first the chlorine passed into each retort is all absorbed by the charge, and only carbonic oxide escapes into the open boxes, where it burns. After a certain time, however, dense fumes are evolved, and the boxes are then closed, while the connecting pipe between the box and the small flue serves to carry off the uncondensed vapours to the chimney.

The reaction which takes place is as follows:—

$$Al_2O_3 + 2NaCl + 3C + 6Cl = 2AlCl_3NaCl + 3CO.$$

The chlorine is passed in for about seventy-two hours in varying quantity, the boxes at the back being opened from time to time by the workmen to ascertain the progress of the distillation. At the end of the time mentioned the chlorine valves are closed, and the boxes at the back of the furnace are all thrown open. The crude double chloride as distilled from the retorts, condenses in the connecting pipe and trickles down into the boxes, where it solidifies in large irregular masses. The yield from a bench of five retorts will average from 1600 to 1800 pounds, which is not far from the theoretical quantity. After the removal of the crude chloride from the condenser boxes the retorts are opened at their charging end, and the residue, which consists of a small quantity of alumina, charcoal, and salt, is raked out and remixed in certain proportions with fresh material, to be used over again. The furnace is immediately re-charged and the same operations repeated, so that from each furnace upwards of 3500 pounds of chloride are obtained weekly. With ten of the twelve furnaces always at work the plant is easily capable of producing 30,000 pounds of chloride per week, or 1,500,000 pounds per annum.

Owing to the presence of iron, both in the materials used (viz. charcoal, alumina, &c.) and in the fire-clay composing the retorts, the distilled chloride always contains a varying proportion of this metal in the form of ferrous and ferric chloride. When it is remembered that it requires 10 pounds of this chloride to produce 1 pound of aluminium by reduction, it will be quite apparent how materially a very small percentage of iron in the chloride will influence the quality of the resulting metal. I may say that, exercising the utmost care as to the purity of the alumina and the charcoal used, and after having the retorts made of special fire-clay containing only a very small percentage of iron, it was found almost impossible to produce upon a large scale a chloride containing less than 0·3 per cent of iron.

This crude double chloride, as it is now called at the works, is highly deliquescent, and varies in colour from a light yellow to a dark red. The variation in colour is not so much due to the varying percentage of iron contained as to the relative proportion of ferric or ferrous chlorides present, and although a sample may be either very dark or quite light, it may still contain only a small percentage of iron if it be present as ferric salt, or a very large percentage if it is in the ferrous condition. Even when exercising all possible precautions, the average analysis of the crude double chloride shows about 0·4 per cent. of iron. The metal subsequently made from this chloride therefore never contained much less than about 5 per cent. of iron, and, as this quantity great injures the capacity of aluminium for drawing into wire, rolling, &c., the metal thus obtained required to be refined. This was successfully accomplished by Mr. Castner and his able assistant, Mr. Cullen, and for some time all the metal made was refined, the iron being lowered to about 2 per cent.

The process, however, was difficult to carry out, and required careful manipulation, but as it then seemed the only remedy for effectively removing the iron, it was adopted and carried on for some time quite successfully, until another invention of Mr. Castner rendered it totally unnecessary. This consisted in purifying the double chloride before reduction. I cannot now explain this process, but I am able to show some of the product. This purified chloride, or pure double chloride, is, as you see, quite white, and is far less deliquescent than the crude, so that it is quite reasonable to infer that this most undesirable property is greatly due to the former presence of iron chlorides. I have seen large quantities containing upwards of 1½ per cent. of iron, or 150 pounds to 10,000 of the chloride, completely purified from iron in a few minutes, so that, whilst the substance before treatment was wholly unfit for the preparation of aluminium, owing to the presence of iron, the result was, like the sample exhibited, a mass containing only 1 pound of iron in 10,000, or 0·01 per cent. The process is extremely simple, and adds little or no appreciable cost to the final product. After treatment, this pure chloride is melted in large iron pots and run into drums similar to those used for storing caustic soda. As far as I am aware, it was generally believed to be an impossibility to remove the iron from anhydrous double chloride of aluminium and sodium, and few, if any, chemists have ever seen a pure white double chloride.

Aluminium Manufacture.

I now come to the final stage of the process, viz. the reduction of the pure double chloride by sodium. This is effected, not in a tube of Bohemian glass, as shown in Mr. Barlow's lecture in 1856, but in a large reverberatory furnace, having an inclined hearth about 6 feet square, the inclination being towards the front of the furnace, through which are several openings at different heights. The pure chloride is ground together with cryolite in about the proportions of two to one, and is then carried to a staging erected above the reducing furnace. The sodium, in large slabs or blocks, is run through a machine similar to an ordinary tobacco-cutting machine, where it is cut into small thin slices; it is then also transferred to the staging above the reducing furnace.

Both materials are now thrown into a large revolving drum, when they become thoroughly mixed. The drum being opened and partially turned, the contents drop out into a car on a tramway directly below. The furnace having been raised to the desired temperature, the dampers of the furnace are all closed to prevent the access of air, the heating gas also being shut off. The car is then moved out on the roof of the furnace until it stands directly over the centre of the hearth. The furnace roof is provided with large hoppers, and through these openings the charge is introduced as quickly as possible. The reaction takes place almost immediately, and the whole charge quickly liquefies. At the end of a certain time the heating gas is again introduced and the charge kept at a moderate temperature for about two hours. At the end of this period the furnace is tapped by driving a bar through the lower opening, which has previously been stopped with a fire-clay plug, and the liquid metal run out in a silver stream into moulds placed below the opening. When the metal has all been drawn off, the slag is allowed to run out into small iron waggons and removed. The openings being again plugged up, the furnace is ready for another charge. From each charge, composed of about 1200 pounds of pure chloride, 600 pounds of cryolite, and 350 pounds of sodium, about 115 to 120 pounds of aluminium are obtained.

The purity of the metal entirely depends upon the purity of the chloride used, and without exercising more than ordinary care the metal tests usually indicate a purity of metal above 99 per cent. On the table is the metal run from a single charge, its weight is 116 pounds, and its composition, as shown by analysis, is 99·2 aluminium, 0·3 silicon, and 0·5 iron. This I believe to be the largest and the purest mass of metal ever made in one operation.

The result of eight or nine charges are laid on one side, and then melted down in the furnace to make a uniform quality, the liquid metal, after a good stirring, being drawn off into moulds. These large ingots, weighing about 60 pounds each, are sent to the casting shop, there to be melted and cast into the ordinary pigs, or other shapes, as may be required for the making of tubes, sheets, or wire, or else used directly for making alloys of either copper or iron.

The following table shows approximately the quantity of each material used in the production of one ton of aluminium:—

Metallic sodium	6,300 pounds
Double chloride	22,400 ,,
Cryolite...	8,000 ,,
Coal	8 tons.

To produce 6,300 pounds of sodium is required:—

Caustic soda	44,000 pounds
Carbide, made from pitch, 12,000 pounds, and iron turnings, 1,000 pounds	7,000 ,,
Crucible castings	2½ tons
Coal	75

For the production of 22,400 pounds double chloride is required:—

Common salt	8,000 pounds
Alumina hydrate	11,000 ,,
Chlorine gas	15,000 ,,
Coal	180 tons.

For the production of 15,000 pounds of chlorine gas is required:—

Hydrochloric acid	180,000 pounds
Limestone dust...	45,000 ,,
Lime	30,000 ,,
Loss of manganese	1,000 ,,

[These figures were rendered more evident by the aid of small blocks, each cut a given size, so as to represent the relative weights of the different materials used to produce one unit of aluminium.]

It might seem, on looking over the above numbers, as if an extraordinary amount of waste occurred, and as if the production is far below that which ought to be obtained, but a study of the figures will show that this is not the case. I would wish to call attention to one item in particular, viz. fuel, it having been remarked that the consumption of coal must prevent cheap production. I think, when it is remembered that coal, such as is used at the works, costs only 4*s.* per ton, while the product is worth £2240 per ton, the cost of coal is not an item of consequence in the cost of production. The total cost of the coal to produce one ton of metal being £50, the actual cost for fuel is less than 6*d.* for every pound of aluminium produced. The ratio of cost of fuel to value of product is indeed less than is the case in making either iron or steel. In concluding my remarks as to the method of manufacture and the process in general, I do not think it is too much to expect, in view of the rapid strides already made, that, in the future, further improvements and modifications will enable aluminium to be produced and sold even at a lower price than appears at present possible.

Properties of Aluminium.

In its physical properties, aluminium widely differs from all the other metals. Its colour is a beautiful white, with a slight blue tint. The intensity of this colour becomes more apparent when the metal has been worked, or when it contains silicon or iron. The surface may be made to take a very high polish, when the blue tint of the metal becomes manifest, or it may be treated with caustic soda and then nitric acid, which will leave the metal quite white. The extensibility or malleability of aluminium is very high, ranking with gold and silver if the metal be of good quality. It may be beaten out into thin leaf quite as easily as either gold or silver, although it requires more careful annealing.

It is extremely ductile, and may be easily drawn, especial care only being required in the annealing.

The excessive sonorousness of aluminium is best shown by example [large suspended bar being struck]. Faraday has remarked, after experiments conducted in his laboratory, that the sound produced by an ingot of aluminium is not simple, and one may distinguish the two sounds by turning the vibrating ingot.

After being cast, it has about the hardness of pure silver, but may be sensibly hardened by hammering.

Its tensile strength varies between 12 and 14 tons to the inch [test sample which was shown having been broken at 13 tons or 27,000 pounds], ordinary cast iron being about 8 tons. Comparing the strength of aluminium in relation to its weight, it is equal to steel of 38 tons tensile strength. The specific gravity of cast aluminium is 2·58, but, after rolling or hammering, this figure is increased to about 2·68.

The specific gravity of aluminium being 1, copper is 3·6, nickel 3·5, silver 4, lead 4·8, gold 7·7.

The fusibility of aluminium has been variously stated as being between that of zinc and silver, or between 600° and 1000° C.

As no reliable information has ever been made public on this subject, my friend Prof. Carnelley undertook to determine it. I was aware, from information gained at the works at Oldbury, that a small increase in the percentage of contained iron materially raised its point of fusion, and it has been undoubtedly due to this cause that such wide limits are given for the melting-point. Under these circumstances two samples were forwarded for testing, of which No. 1, containing ½ per cent. of iron, had a melting-point of 700° C. No. 2, containing 5 per cent. of iron, does not melt at 700°, and only softens somewhat above that temperature, but undergoes incipient fusion at 730°.

According to Faraday, aluminium ranks very high among metallic conductors of heat and electricity, and he found that it conducted heat better than either silver or copper. The specific heat is also very high, which accounts for length of time required for an ingot of the metal to either melt or get cold after being cast.

Chemically, its properties are well worthy of study.

Air, either wet or dry, has absolutely no effect on aluminium at the ordinary temperature, but this property is only possessed by a very pure quality of metal, and the pure metal in mass undergoes only slight oxidation even at the melting-point of platinum.

Thin leaf, however, when heated in a current of oxygen, burns with a brilliant, bluish-white light. [Experiment shown.] If the metal be pure, water has no effect on it whatever, even at a red-heat. Sulphur and its compounds also are without action on it, while, under the same circumstances, nearly all metals would be discoloured with great rapidity. [Experiment shown using silver and aluminium under the same conditions.]

Dilute sulphuric acid and nitric acid, both diluted and concentrated, have no effect on it, although it may be dissolved in either hydrochloric acid or caustic alkali. Heating in an atmosphere of chlorine it burns with a vivid light, producing aluminium chloride. [Experiment shown.] In connection with the subject it may be of interest to state the true melting-point of the double chloride of aluminium and sodium, which has always been given at 170° to 180° C., but which Mr. Baker, the chemist to the works, finds lies between 125° and 130° C.

Uses of Aluminium.

Its uses, unalloyed, have heretofore been greatly restricted. This is, I believe, alone owing to its former high price, for no metal possessing the properties of aluminium could help coming into larger use if its cost were moderate. Much has been said as to the impossibility of soldering it being against its popular use, but I believe that this difficulty will now soon be overcome. The following are a few of the purposes to which it is at present put: telescope tubes, marine glasses, eye-glasses and sextants, especially on account of its lightness; fine wire for the making of lace, embroidery, &c; leaf in the place of silver leaf, sabre sheaths, sword handles, &c., statuettes and works of art, jewellery and delicate physical apparatus, culinary utensils, harness fittings, metallic parts of soldiers' uniforms, dental purposes, surgical instruments, reflectors (it not being tarnished by the products of combustion), photographic apparatus, aëronautical and engineering purposes, and especially for the making of alloys.

Alloys of Aluminium.

The most important alloys of aluminium are those made with copper. These alloys were first prepared by Dr. Percy, in England, and now give promise of being largely used. The alloy produced by the addition of 10 per cent. of aluminium to copper, the maximum amount that can be used to produce a satisfactory alloy, is known as aluminium bronze. Bronzes, however, are made which contain smaller amounts of aluminium, possessing in a degree the valuable properties of the 10 per cent. bronze. According to the percentage of aluminium up to 10 per cent., the colour varies from red gold to pale yellow. The 10 per cent. alloy takes a fine polish, and has the colour of jeweller's gold. The 5 per cent. alloy is not quite so hard, the colour being very similar to that of pure gold. I am indebted to Prof. Roberts Austen for a mould in which the gold at the mint is usually cast, and in this I have had prepared ingots of the 10 and 5 per cent. alloy, so that a comparison may be made of the colour of these with a gold ingot cast in the same mould, for the loan of which I have to thank Messrs. Johnson, Matthey, and Co., all of which are before you.

I have also ingots of the same size, of pure aluminium, from which an idea of the relative weights of gold and aluminium may be obtained.

To arrive at perfection in the making of these alloys, not only is it required that the aluminium used should be of good quality, but also that the copper must be of the very best obtainable. For this purpose only the best brands of Lake Superior copper should be used. Inferior brands of copper or any impurities in the alloy give poor results. The alloys all possess a good colour, polish well, keep their colour far better than all other copper alloys, are extremely malleable and ductile, can be worked either hot or cold, easily engraved, the higher grades have an elasticity exceeding steel, are easily cast into complicated objects, do not lose in remelting, and are possessed of great strength, dependent, of course, on the purity and percentage of contained aluminium. The 10 per cent. alloy, when cast, has a tensile strength of between 70,000 and 80,000 pounds per square inch, but when hammered or worked, the test exceeds 100,000 pounds. [A sample shown broke at 105,000 pounds.]

An attempt to enumerate either the present uses or the possible future commercial value of these alloys is beyond my present purpose. I may, however, remark that they are not only adapted to take the place of bronze, brass, and steel, but they so far surpass all of those metals, both physically and chemically, as to make their extended use assured. [Sheets, rods, tubes, wire, and ingots shown.]

But even a more important use of aluminium seems to be its employment in the iron industry, of which it promises shortly to become an important factor, owing to certain effects which it produces when present, even in the most minute proportions. Experiments are now being carried on at numerous iron and steel works, in England, on the Continent, and in America. The results so far attained are greatly at variance, for whilst in the majority of cases the improvements made have encouraged the continuance of the trials, in others the result has not been satisfactory. On this point I would wish to say to those who may contemplate making use of aluminium in this direction, that it would be advisable before trying their experiments to ascertain whether the aluminium alloy they may purchase actually contains any aluminium at all, for some of the so-called aluminium alloys contain little or no aluminium, and this may doubtless account for the negative results obtained. Again, others contain such varying proportions of carbon, silicon, and other impurities, as to render their use highly objectionable.

It seems to be a prevailing idea with some people, that, because aluminium is so light compared with iron, they cannot be directly alloyed, and, furthermore, that, for the same reason, alloys made by the direct melting together of the two metals would not be equal to an alloy where both metals are reduced together. Now, of course, this is not the case, and the statement has been put forward by those who were only able to make the alloys in one way.

Aluminium added to molten iron and steel lowers their melting-points, consequently increases the fluidity of the metal, and causes it to run easily into moulds and set there, without entrapping air and other gases, which serve to form blow-holes and similar imperfections. It is already used by a large number of steel founders, and seems to render the production of sound steel castings more certain and easy than is otherwise possible.

One of the most remarkable applications of the property which aluminium possesses of lowering the melting-point of iron has been made use of by Mr. Nordenfeldt in the production of castings of wrought iron.

Aluminium forms alloys with most other metals, and although each possesses peculiar properties which in the future may be utilized, at present they are but little used.

In conclusion, I beg to call your attention to the wood models on the table, one being representative of aluminium, the other aluminium bronze. The originals of these models are now in the Paris Exhibition, each weighing 1000 pounds. With regard to aluminium bronze, I cannot speak positively, but the block of pure aluminium is undoubtedly the largest casting ever made in this most wonderful metal. I have to thank the Directors of the Aluminium Company, and especially Mr. Castner, for furnishing me with the interesting series of specimens of raw and manufactured metal for illustrating my discourse.

THE PALÆONTOLOGY OF STURGEONS.[1]

THE palæontological history of the Acipenseroid fishes is at present very imperfectly known. In the existing fauna, only two families are recognizable—that of the Acipenseridæ, with series of bony dermal scutes upon the trunk, and that of Polyodontidæ, destitute of any such armour ; both these occupy so low a position in the scale of organization, that considerable evidence of numerous extinct allies might naturally be expected to occur among the fossils of the older rocks. Such evidence, however, can as yet be only slightly recognized. Remains of typical members of the two existing families seem to occur as low in the Tertiary series as the Eocene formation. Pectoral spines and dermal scutes, indistinguishable from those of the living *Acipenser*, are met with in the Upper Eocene of the Hampshire Basin, and the London Clay (Lower Eocene) of the Isle of Sheppey ; and Prof. E. D. Cope has described a fish (*Crossopholis*) from the Eocene Green River Shales of Wyoming, U.S.A., differing only from the typical Polyodontidæ in the possession of rudimentary scales upon the sides of the trunk.

The only Cretaceous fossils yet known, which are at all comparable with characteristic parts of the Acipenseroid skeleton, are two specimens from the English Chalk. The remains of a tail from Gravesend, in the British Museum, are most satisfactorily interpreted as belonging to a fish of this type ; and the extremity of a snout from Sussex, in the Willett Collection, Brighton, seems to be more nearly paralleled by the snout of *Acipenser* than by that of any other known fish. Other fragmentary evidence of Acipenseroids in Upper Jurassic rocks will probably soon be recognized, thanks especially to the investigations of Mr. Alfred N. Leeds in the Oxford Clay of Peterborough ; but the most complete and unmistakable fossils occur in the English Lower Jurassic—both in the Upper Lias of Whitby and the Lower Lias of Lyme Regis.

The gigantic Acipenseroid of Whitby was first noticed by Agassiz, under the name of *Gyrosteus mirabilis*, but it has not hitherto been scientifically investigated and described. The head seems to have been enveloped in few membrane bones, none externally ornamented or covered with ganoine ; the chondrocranium is scarcely ossified ; and the jaws are toothless. The opercular apparatus is incomplete, without branchiostegal rays ; and the membrane bones of the pectoral arch are unornamented. There is evidence of a persistent notochord, and a few ossified ribs occur anteriorly. The upper lobe of the tail exhibits the characteristic series of large fulcra, and the trunk seems to have been naked.

Gyrosteus thus conforms to the normal Acipenseroid type as represented at the present day ; but the genus of the Lower Lias, *Chondrosteus*, displays many striking differences. As pointed out especially by Dr. R. H. Traquair, these differences tend to place the fish half-way between the modern Sturgeons and the typically Palæozoic group of Palæoniscidæ. The roof of the skull exhibits definite frontal, parietal, squamosal, and supra-temporal membrane bones ; in addition to the operculum and sub-operculum there are distinct branchiostegal rays ; and in minor features there are several interesting resemblances to points of Palæoniscid osteology. Dr. Traquair, indeed, places the Palæoniscidæ in the "Acipenseroidei" ; and it may be that, as no typical Acipenseroids of corresponding antiquity are known, the Sturgeons and Polyodons are the somewhat degenerate descendants of Palæozoic fishes upon this biological level. At the same time, it must be remembered that the Palæoniscidæ pass by several known gradations into the characteristic bony Ganoids of Mesozoic age ; and if the ascertained facts of palæichthyology are already a sufficient basis for phylogenetic speculation, it thus appears that two diverging series arise from this primitive stock. In his latest classification (*American Naturalist*, 1887, p. 1018), Prof. Cope admits the origin of the later Ganoids from fishes of a Palæoniscid type ; but, on the assumption that the basal cartilages (baseosts) of the pelvic fin in Palæoniscidæ were minute or absent, the Sturgeons are placed lower in the series than the latter. Under any circumstances, the relative development of a single structural feature is a slight point for the distinction of two "superorders"; and if "Podopterygia" and "Actinopterygia" are to hold separate rank, the Palæoniscidæ (so far as all positive evidence is concerned) may be as justly placed in the former as in the latter.

NITRATE OF SODA, AND THE NITRATE COUNTRY.

I.

TILL lately, nitrate of soda has only been known to the few who dealt in manures, or who were engaged in chemical manufactures ; but within the last two years the British public have invested vast sums of money in the shares of Nitrate Companies, while the presence in society of live millionaires who have made their money in Tarapaca, and the strong personality of a "Nitrate King," have made "nitrates" a household word.

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[1] Abstract of a Paper, by A. Smith Woodward, read before the Geologists' Association on January 4.